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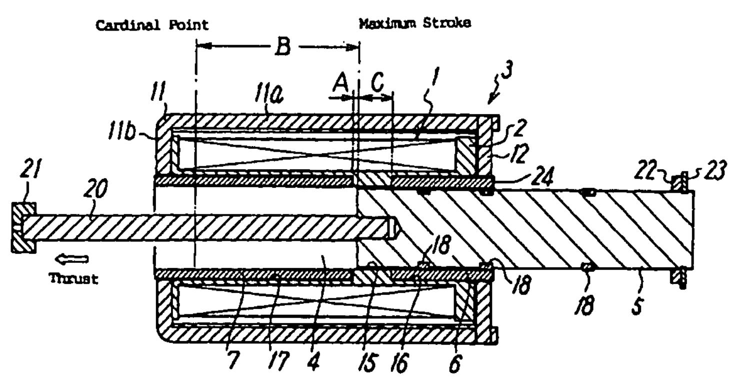
(54) **Electromagnetic actuator**

(57) An electromagnetic actuator comprises an electromagnetic coil 1, a magnetic frame 3 arranged on the periphery thereof, a movable iron core 5 slidable in a central hole 4 of the coil 1, a first sleeve 6 coupled with the magnetic frame 3 at one end side of the central hole 4 of the coil, and a second sleeve 7 coupled with the magnetic frame 3 at the other end side of the central hole 4. The second sleeve 7 has an end spaced from the first sleeve 6 in the axial direction and in close proximity to the movable iron core 5 when the movable iron core 5 is at a back stroke end. The electromagnetic actuator has a large stroke and is capable of producing the maximum thrust at a retreated stroke end, is simple in structure and easy to manufacture.

FIG. 1



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Description

[0001] The present invention relates to an electromagnetic actuator for moving a movable iron core inserted through a central hole of an electromagnetic coil in the axial direction of the central hole by conducting a current through the electromagnetic coil.

[0002] It is well known to provide an electromagnetic actuator of the type to which the invention relates. However, ordinarily, the thrust of the electromagnetic actuator is initially small and the thrust gradually increases after the electromagnetic actuator is started, as shown by the dotted line in Fig. 6.

[0003] However, in operation of a variety of apparatuses and members of a manufacturing line (for example, forcing out on a roller conveyor, pushing out from a shooter, or the like), when a driving instruction signal is outputted, there are not a few occasions when an operation in response to the signal (for example, the operation of forcing out an object) is required to be performed as quickly as possible. On such an occasion, when a quick operation is to be performed, a comparatively larger force is required for activation. For example, when forcing out an object of a certain weight or activating a movable member, a large force may be required for activating it, but once activated, oftentimes a large force is no longer required as the operation can be continued by the inertia of the object, member etc. Therefore, if the initial thrust is increased and the speed of the responsive operation is improved, processing time in a variety of manufacturing lines can be shortened, and productivity thereof can be increased. Of course, the need to perform the quickest possible responsive operation to a driving instruction signal is not limited to manufacturing lines but also exists in a variety of technical fields.

[0004] A conventional electromagnetic actuator, having a small thrust upon start-up by current conduction as described heretofore, is unsuitable to fulfil such a need and in order to meet the need the known actuator would require an increased initial thrust. However, the thrust cannot be so increased as to cause a damage to an object on which the thrust is applied, and therefore it may also be necessary to adjust the thrust while sufficiently increasing the initial thrust.

[0005] An object of the present invention is to provide an electromagnetic actuator having a large stroke which is adapted to maximise the thrust thereof upon starting.

[0006] Another object of the present invention is to provide an electromagnetic actuator, the thrust of which is adjustable but which produces the maximum thrust upon starting.

[0007] Still another object of the present invention is to provide such actuators in a form which has a simple structure and is easy to manufacture.

[0008] An electromagnetic actuator of the present invention has an electromagnetic coil, a magnetic frame made of magnetic material arranged on the periphery of the electromagnetic coil, and a movable iron core which is inserted through a central hole of the coil and is slidable in the axial direction of the central hole of the coil. The electromagnetic actuator is characterized by comprising a first sleeve which is made of a magnetic material to be magnetically coupled with the magnetic frame at one end side of the central hole of the coil, and mutually engaged with the movable iron core over the entire stroke of the movable iron core, and a second sleeve which is made of a magnetic material to be magnetically coupled with the magnetic frame at the other end side of the central hole, and spaced apart from the first sleeve, and by an end of the second sleeve opposing the first sleeve being in close proximity to the movable iron core but not in engagement therewith when the iron core is at the end of a back, or retracted, stroke.

[0009] In an electromagnetic actuator with the above-described configuration, when a current is conducted through the electromagnetic coil with the movable iron core at the retreated stroke end, a magnetic flux is generated on a periphery of the coil. However, since there is a space in the axial direction between the first sleeve and the second sleeve, the magnetic flux passes through inside the movable iron core. At the same time, since an end of the second sleeve opposing the first sleeve is in a position in close proximity to the movable iron core, the high density magnetic flux causes a large electromagnetic attraction in the axial direction to be exerted between the second sleeve and the movable iron core. Accordingly, maximum thrust can be produced in the movable iron core upon starting of the actuator by current conduction.

[0010] When the movable iron core has started to move and a portion thereof has entered the second sleeve, the radial components of the magnetic flux between the second sleeve and the movable iron core increase, and the electromagnetic attraction being exerted in the axial direction between them is gradually oriented toward the radial direction which orthogonally crosses the thrust. Since the oriented force increases in proportion to an area of the second sleeve overlapping the movable iron core, the thrust gradually decreases in accordance with amount moved by the movable iron core.

[0011] The diameter of the end of the movable iron core adjacent the second sleeve can be reduced in comparison with the remainder to adjust the starting thrust. In this way, the thrust can be somewhat adjusted while still producing the maximum thrust at approximately the retreated stroke end.

[0012] Further, the first sleeve and the second sleeve can be concentrically joined by a bobbin which is wound by the electromagnetic coil, or a guide tube made of a nonmagnetic material can be inserted into the first sleeve and the second sleeve to concentrically join them. Thereby the movable iron core can be operated in a stabilized way.

[0013] Furthermore, the first sleeve and/or the sec-

ond sleeve can be formed by rolling a plate made of a magnetic material, thereby enabling the electromagnetic actuator to have a simple structure and be easy to manufacture.

[0014] The invention will now be described by way of example and with reference to the accompanying drawings in which:

Fig. 1 shows a cross-sectional view of a first embodiment of an electromagnetic actuator according to the present invention.
Fig. 2 shows a cross-sectional view of a second embodiment of an electromagnetic actuator according to the present invention.
Fig. 3 shows a cross-sectional view of a third embodiment of an electromagnetic actuator according to the present invention.
Fig. 4 shows a cross-sectional view of a fourth embodiment of an electromagnetic actuator according to the present invention.
Fig. 5 shows a perspective view of an exemplary structure of a first and second sleeve.
Fig. 6 shows an explanatory chart describing relationship between a stroke and a thrust.

[0015] Fig. 1 shows a first embodiment of an electromagnetic actuator comprising an electromagnetic coil 1 wound around a bobbin 2, a magnetic frame 3 made of a magnetic material and arranged on a periphery of the coil, a movable iron core 5 being inserted through a central hole 4 of the coil 1 and slidable in the axial direction of the central hole, and a first sleeve 6 and a second sleeve 7 which are coupled with the magnetic frame 3.

[0016] The magnetic frame 3 made of the magnetic material which surrounds the electromagnetic coil 1 comprises a frame body 11 having a portion 11b which is bent toward the central hole 4 of the coil at one end of the outer periphery 11a, and a plate 12 fixed to the frame body 11 at the opposite end to the bent portion 11b to provide a magnetic path around the coil 1.

[0017] The first sleeve 6 is made of a magnetic material and coupled with the magnetic frame 3 at one end of the central hole 4 of the coil 1, namely at the plate 12 side of the magnetic frame 3. The first sleeve 6 is arranged to engage with the movable iron core 5 over an entire stroke of the movable iron core so as to be position around of the movable iron core 5 even when the movable iron core 5 is at the retreated stroke end as shown in Fig. 1. More particularly, the first sleeve 6 extends from an inner end of the plate 12 which constitutes a part of the magnetic frame 3 into the central hole 4 of the coil 1, and ends a distance C in front of an end face of the movable iron core 5 when the core 5 is at the retreated stroke end.

[0018] The second sleeve 7 is also made of a magnetic material and is coupled with the other end of the central hole 4 of the coil, namely with the bent portion 11b side of the frame body 11. The second sleeve 7 has an end thereof spaced in the axial direction from the first sleeve 6 by a distance A+C, and when the movable iron core 5 is at the retreated stroke end as shown in Fig. 1, an end thereof opposing the first sleeve 6 is in a position in close proximity to the movable iron core 5 but is not substantially engaged therewith and is spaced therefrom by a micro-distance A. The position needs to be one where a large electromagnetic attraction in the axial direction is exerted on the movable iron core 5 positioned at the retreated stroke end, when a current is conducted through the coil 1. Depending on the situation, the distance A may be substantially zero. It should be noted that in order to increase the stroke of the movable iron core 5, the second sleeve 7 is generally more elongate than the first sleeve 6.

[0019] The first sleeve 6 and the second sleeve 7 should be concentrically arranged as the movable iron core 5 moves therethrough at a high speed. For this purpose, on an inner peripheral surface of the bobbin 2 having the electromagnetic coil 1 wound therearound, a convexity 15 is provided for setting the space (A + C) between the first sleeve 6 and the second sleeve 7, and on both sides of the convexity 15, depressed portions 16 and 17 are provided for engaging the first sleeve 6 and the second sleeve 7 therewith. By having the sleeve 6 and the sleeve 7 tightly engaged with the depressed portions 16 and 17, both sleeves 6 and 7 are concentrically joined together to have the inner surfaces thereof smoothly coupled.

[0020] The movable iron core 5 has a number of guide rings 18 fitted on the periphery thereof for smooth sliding of the movable iron core 5 inside the first sleeve 6 and the second sleeve 7. It is desirable to have at least two guide rings 18 at all times in the central hole 4. Further, at one end of the movable iron core 5, there is a push rod 20 made of a nonmagnetic material for transmitting a generated thrust and the tip of the push rod is covered by a cap 21. Furthermore, on the other end of the movable iron core 5, retained by a collar 23 is a cushion member 22 for setting a stop position for the movable iron core 5 by abutting a receiving seat 24 formed on an outer end of the first sleeve 6, when the movable iron core 5 is driven by a current conducted through the coil 1. The push rod 20 can be fixed to the movable iron core 5 by means of injection, welding, or the like, while the cap 21 at the tip thereof can be formed with a synthetic resin, rubber, metal, or the like, and adhered to the tip of the push rod by means of injection, arresting, welding, or the like.

[0021] In the electromagnetic actuator having the above-described configuration, when a current is conducted through the electromagnetic oil 1 in a state as shown in Fig. 1 where the movable iron core 5 is at the retreated stroke end, a magnetic flux is generated on the periphery of the coil 1. However, as there is a space (A + C) in the axial direction between the first sleeve 6 and the second sleeve 7, the magnetic flux passes

through inside the movable iron core 5. At the same time, since the end of the second sleeve 7 opposing the first sleeve 6 is in close proximity to the movable iron core 5, the high density magnetic flux causes a large electromagnetic attraction in the axial direction to be exerted between the second sleeve 7 and the movable iron core 5. Consequently the maximum thrust can be produced for the movable iron core upon starting by conducting a current.

[0022] When the movable iron core 5 starts to move and travels a distance A a portion thereof enters the second sleeve 7. Then the radial components of the magnetic flux between the second sleeve 7 and the movable iron core 5 are increased, and the electromagnetic attraction being exerted in the axial direction therebetween is gradually oriented toward the radial direction which orthogonally crosses the thrust. Since the oriented force increases in proportion to an area of the second sleeve 7 overlapped by the movable iron core, the thrust gradually decreases in accordance with distance moved by the movable iron core 5. The movable iron core 5, after being driven for a stroke B, comes to stop as cushion member 22 abuts receiving seat 24 of the first sleeve 6. Movement of the movable iron core 5 is transmitted by the push rod 20 coupled thereto.

[0023] Fig. 6 schematically shows the relationship between stroke and thrust of a movable iron core of the present embodiment in comparison with a general electromagnetic actuator. In the general electromagnetic actuator, the initial thrust upon starting by conducting a current is small as shown by a doffed line in the drawing, and the thrust gradually increases after the operation is started. In the electromagnetic actuator of the present embodiment, however, the thrust can be maximized in the vicinity of the starting time of the operation enabling driving of an object by a large thrust, as shown by a solid line in the drawing. The thrust decreases thereafter.

[0024] A preferred embodiment of the above-described electromagnetic actuator in the exemplary structure of Fig. 1, may have: stroke B≥ 10mm; A = O to 5mm; C≥ 2mm, and [length of the first sleeve] < [length of the second sleeve]. However, these values are simply exemplary.

[0025] Fig. 2 and Fig. 3 respectively show a second embodiment and a third embodiment of an electromagnetic actuator according to the present invention. Since the electromagnetic actuators of these embodiments have substantially the same configuration as the first embodiment except for structure of a movable iron core 5A and a movable iron core 5B, only the differences will be described and like reference numerals will be used for like parts.

[0026] The movable iron core 5A shown in Fig. 2 is provided with a tapered cut-away 25A which is formed by cutting to taperingly reduce the diameter of the end thereof on the sleeve 7 side for adjusting the initial thrust. The thrust of the movable iron core 5A can be adjusted in accordance with degree of cuffing of the cut-away 25A, while producing the maximum thrust in the vicinity of the retreated stroke end.

[0027] The movable iron core 5B shown in Fig. 3 is similarly provided with a cut-away 25B at the second sleeve 7 side end of the movable iron core 5B for adjusting the thrust. The cut-away 25B is, however, formed by cutting to uniformly reduce the diameter of the movable iron core 5B in a step-shape. Therefore, the thrust can be adjusted in accordance with degree of the cutting but in a different way to the embodiment shown in Fig. 2.

[0028] It should be noted that the above-described cut-away may have a variety of forms suited for the thrust adjustment, in addition to structures illustrated in Fig. 2 and Fig. 3.

[0029] Fig. 4 shows a configuration of a fourth embodiment of an electromagnetic actuator according to the present invention. In the fourth embodiment, a guide tube 26 made of a nonmagnetic material is inserted into the first sleeve 6 and the second sleeve 7, thereby concentrically joining the first sleeve 6 and the second sleeve 7. When the guide tube 26 is used, bent portions 6a and 7a are formed at outer ends respectively of the first sleeve 6 and the second sleeve 7. The first sleeve 6 and the second sleeve 7 are inserted into the central hole 4 of the coil 1 until the bent portions 6a and 7a abut the outer ends of the magnetic frame 3. Then, the guide tube 26 is inserted into both sleeves 6 and 7, and by forming outwardly bending bent portions 26a at both ends of the guide tube 26, the sleeves 6 and 7 can be simply secured at the required positions together with the guide tube 26. Further, when the guide tube 26 is secured in the central hole 4 of the coil, a bent portion 26a may be formed in advance at one end thereof.

[0030] When such guide tube 26 is used, since the movable iron core 5 slides inside the single guide tube 26, it is not always necessary to smoothen the sliding by providing the guide rings 18 on the movable iron core 5 as in the first to the third embodiments. Instead, an appropriate structure may be to have the movable iron core directly slide in the guide tube 26. Moreover, for the guide tube 26, a material suitable for sliding of the movable iron core 5 may be used.

[0031] Aside from the guide tube 26, the fourth embodiment is the same as the first embodiment and like reference numerals are used for like parts.

[0032] Further, in the electromagnetic actuators of the above-described respective embodiments, the first sleeve 6 and the second sleeve 7 may be formed by rolling a square plate 28 made of a magnetic material into a cylinder as shown in Fig. 5. In this case, it is not necessary to couple joining portions of both ends of the rolled plate 28, and a joint clearance 29 causes no problem.

[0033] The guide tube 26 used in the fourth embodiment may also be formed by rolling a square plate made of nonmagnetic material into a cylinder. In this

case as well, it is not necessary to couple joining portions of both ends of the rolled plate, and a joint clearance causes no problem.

[0034] The electromagnetic actuators described in detail hereabove, have a large stroke which is made to produce the maximum thrust at the retreated stroke end. Furthermore, the thrust may be made somewhat adjustable while still producing the maximum thrust in the vicinity of the retreated stroke end. Moreover, the actuators have a simple structure and are easy to manufacture.

Claims

1. An electromagnetic actuator comprising an electromagnetic coil having a central hole, a magnetic frame made of a magnetic material surrounding the coil, an iron core movable within the coil central hole in the axial direction thereof, a first sleeve made of a magnetic material which is magnetically coupled with the magnetic frame by being inserted into one end of the central hole and is engaged with the movable iron core over the entire stroke of the movable iron core, and a second sleeve made of a magnetic material which is magnetically coupled with the magnetic frame by being inserted into the other end of the central hole to a position in which the second sleeve is axially spaced from the first sleeve and the end thereof closest to the first sleeve is in close or adjacent proximity to the movable iron core but not in engagement therewith when the movable iron core is at the end of a back stroke, wherein the second sleeve is arranged to be gradually engaged with the movable iron core as the movable iron core advances.

2. An electromagnetic actuator according to Claim 1, wherein the end of the movable iron core closest to the second sleeve has a smaller cross-section than the remainder of the core.

3. An electromagnetic actuator according to either Claim 1 or Claim 2 wherein an annular protrusion is provided on an inner peripheral surface of the central hole of the bobbin, and wherein the sleeves are inserted into the central hole to a position touching the protrusion such that the space between the sleeves is set by the protrusion.

4. An electromagnetic actuator according to any preceding claim, wherein a guide tube made of a nonmagnetic material and of a length greater than the lengths of the first and second sleeves is inserted into the sleeves.

5. An electromagnetic actuator according to any preceding claim, wherein at least one of the first sleeve and the second sleeve is formed by cylindrical rolling of a plate made of a magnetic material.

6. An electromagnetic actuator according to any preceding claim, wherein the movable iron core has a push rod made of a nonmagnetic material at a front end thereof and a cushion member at a rear end thereof for shock absorption at an advanced stroke end.

FIG. 1

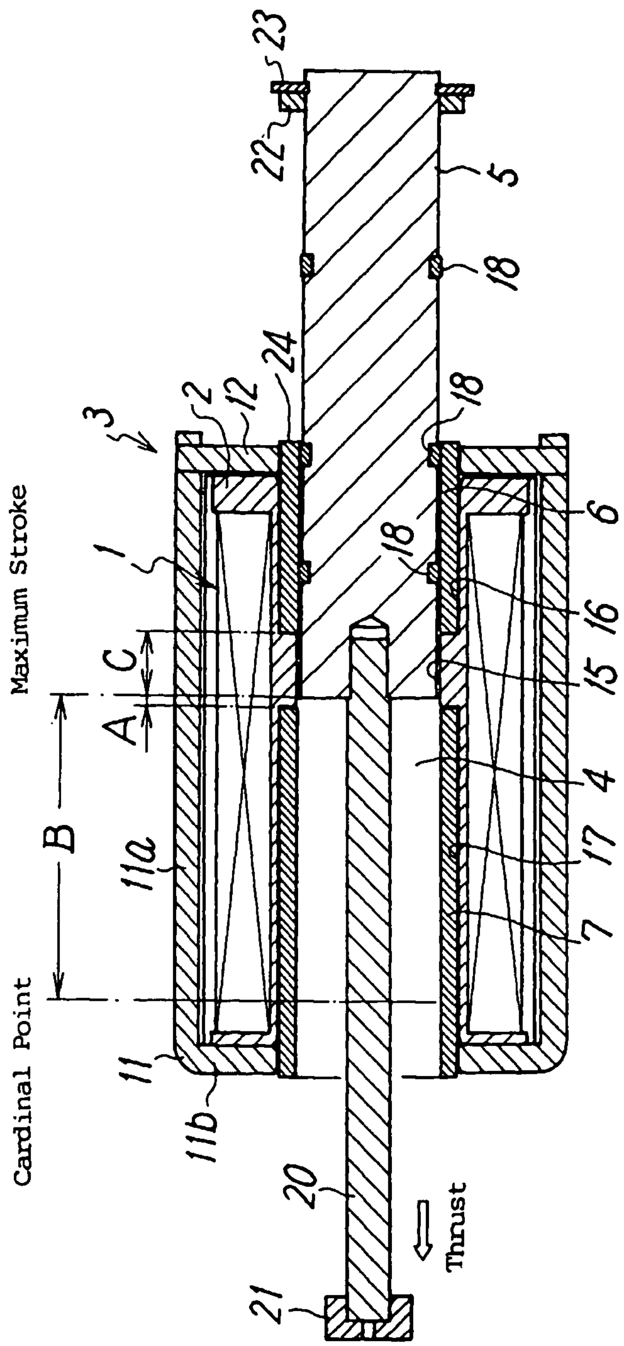
Maximum Stroke
Cardinal Point
Thrust
A
B
C
1
2
3
4
5
6
7
11
11a
11b
12
15
16
17
18
20
21
22
23
24

FIG. 2

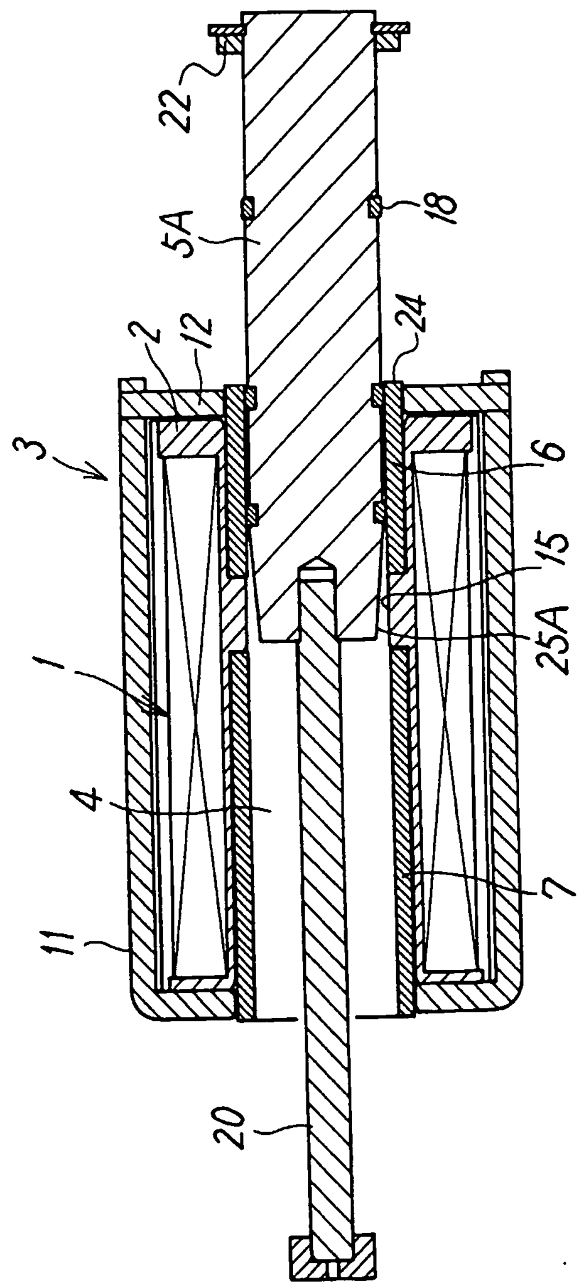

FIG. 3

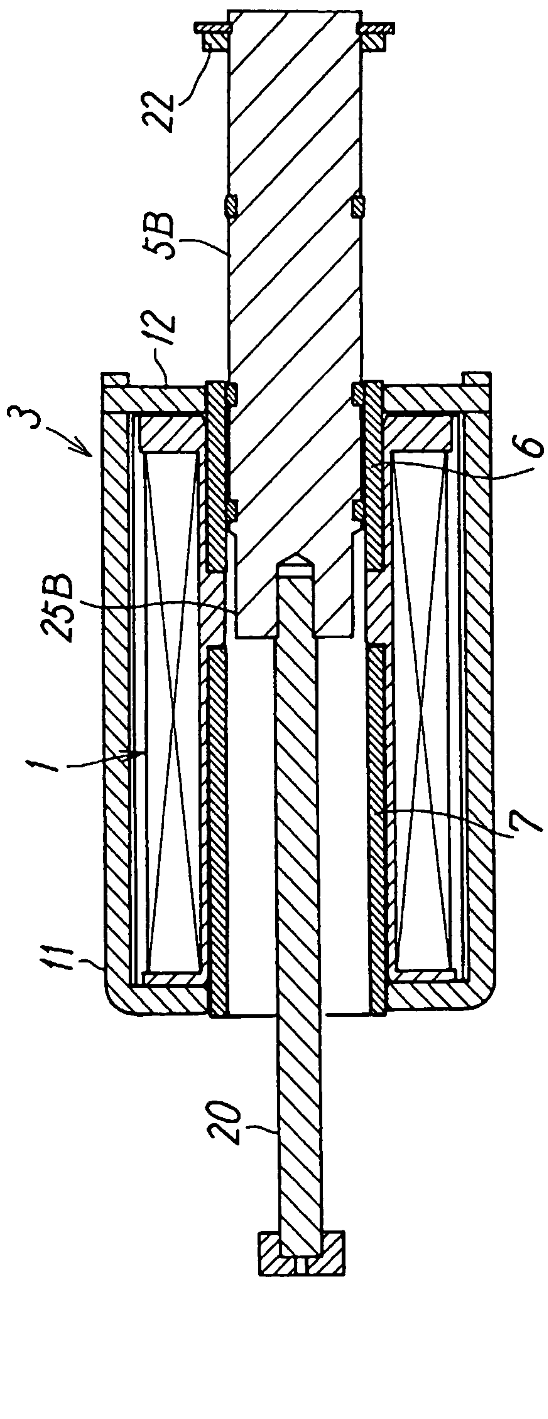

FIG. 4

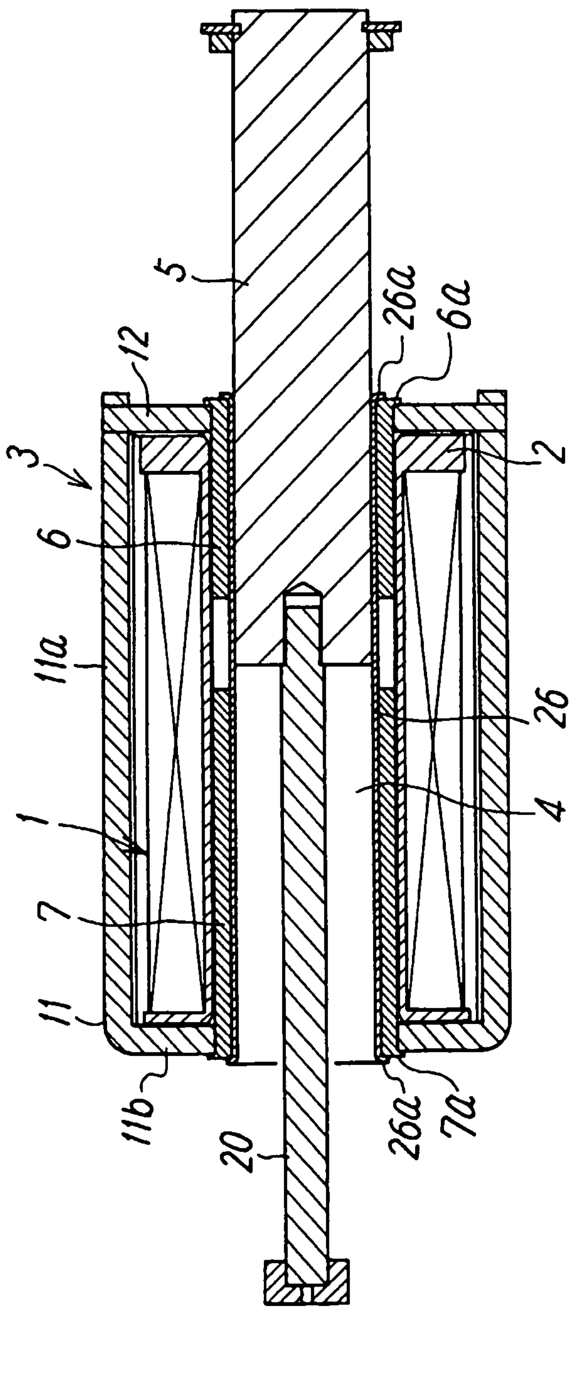

FIG. 5

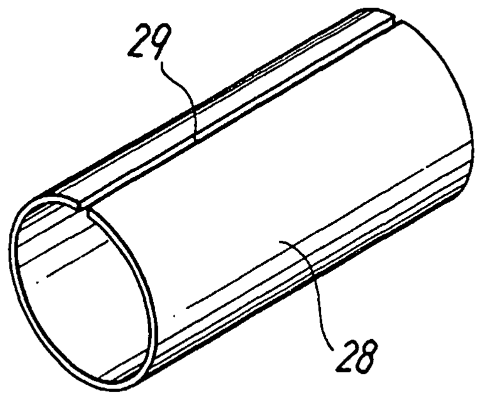
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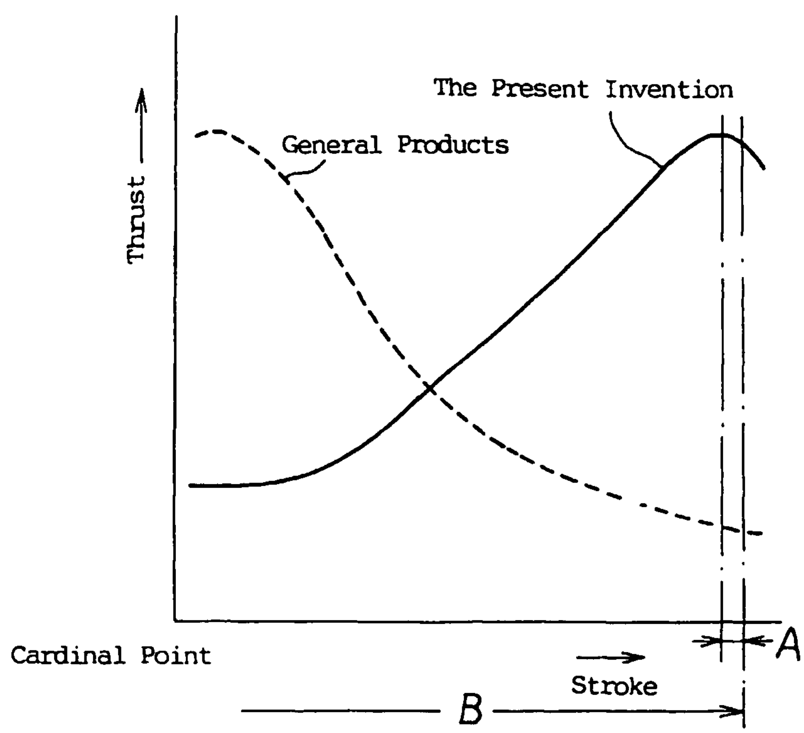
FIG. 6


Thrust
The Present Invention
General Products
Cardinal Point
Stroke
A
B

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EUROPEAN SEARCH REPORT

Application Number
EP 00 30 3834

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
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X	GB 1 279 509 A (BUERKERT) 28 June 1972 (1972-06-28)	1	
A	* column 1, line 30 - column 3, line 47; claim 1; figure 1 *	3,4	
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A	US 3 598 360 A (MERRINER DELBERT L ET AL) 10 August 1971 (1971-08-10) * column 1, line 60,61; figure 2 *	5	
A	US 5 326 070 A (BARON TIBOR) 5 July 1994 (1994-07-05) * column 5, line 60-64; figure 2 *	6	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)

H01F

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 September 2000	Durville, G

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